High-Fidelity Simulation of a Computer Room

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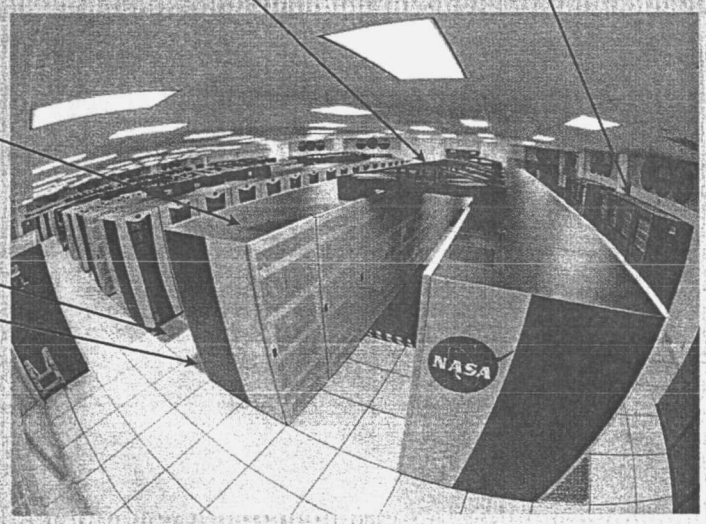
Outline

- Introduction to Columbia
- Motivation
- Methodology
- Results
- Concluding remarks

Columbia

- 10240 CPUs
  - *20 SGI Altix superclusters (512 CPUS/cluster)*
  - *Intel Itanium® 2 processors (1.5 GHz)*
  - *1TB memory/cluster, 440TB storage*
  - *SGI's NUMAflex architecture (Infiniband)*
- Top performance to date: 51.9 TFlops
  - *Linpack benchmark*
  - *#2 on the TOP500 list*
- Built in <5 months, fully operational

http://www.nas.nasa.gov/About/Projects/Columbia/columbia.html



Columbia: NASA Ames

Advanced Supercomputing Division

Motivation

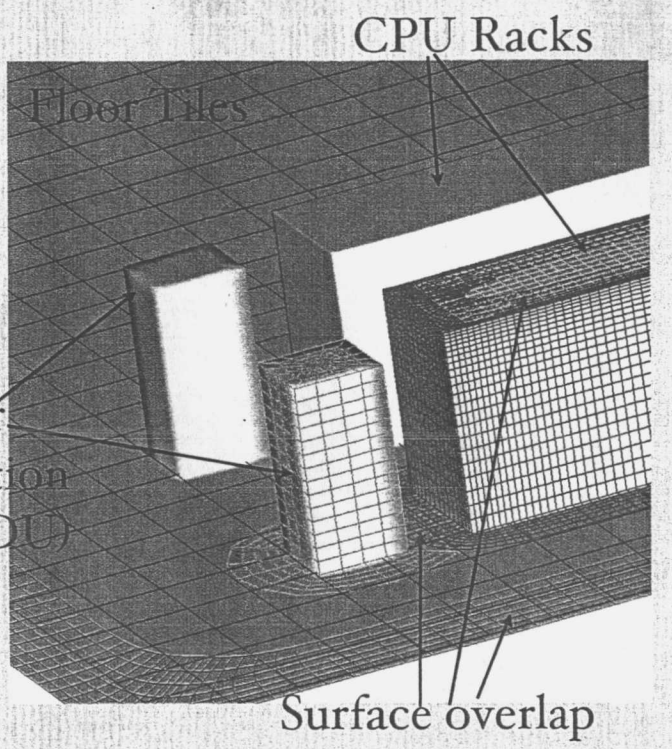
- Need to know if cooling is adequate
  - *Identify High-temperature regions*
  - *Effect of cable trays in hot isles*
- Find dead-zones
  - *Areas of stagnated air*
- Short-cycling
  - *Cold air from floor tiles returning directly to coolers*
  - *Hot air from racks returning to racks*
- Deadline: 6 weeks

Methodology

- Overset mesh approach
- Geometric model
  - *Non-CAD / script-based modeling*
  - *Many structured meshes make up the domain of interest*
  - *Chimera Grid Tools (CGT)*
- PDE solution model
  - *Compressible Navier-Stokes equations*
  - *Boundary conditions*
  - *Overflow2 solver*

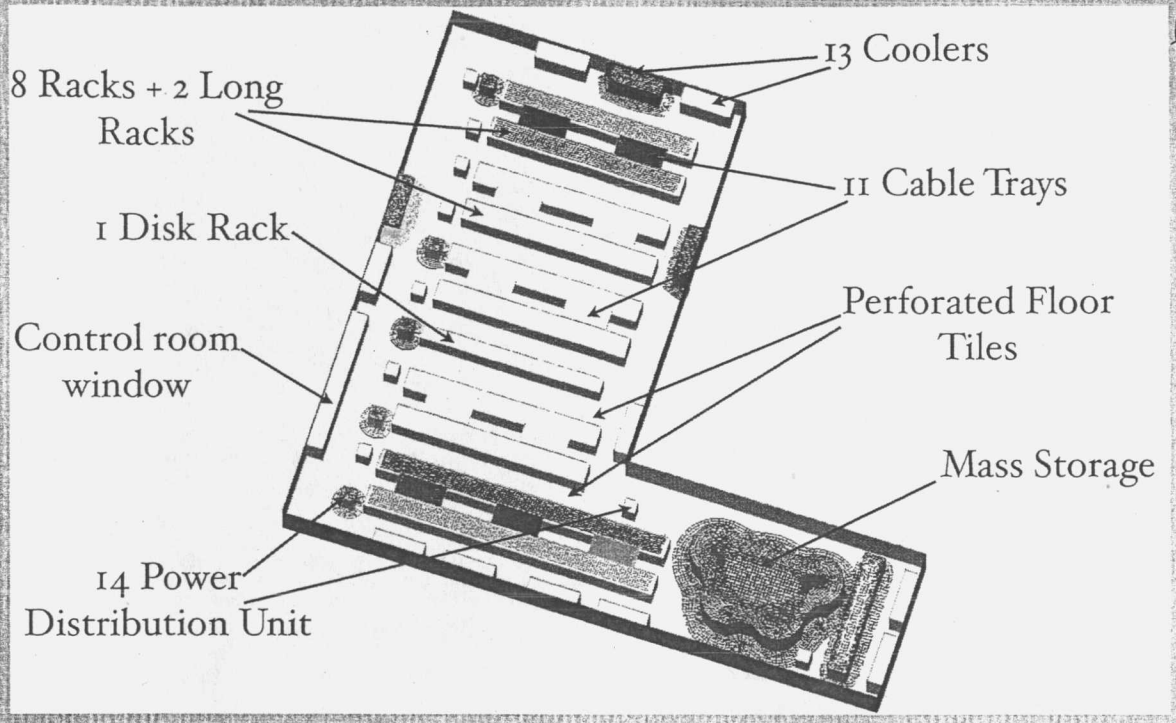
Overset Mesh Approach

- Body-fitted grids
  - *Complex geometry*
- Geometry
  - *Quadrilateral cells*
  - *Overlapping*
- Volume
  - *Hexahedral cells*
  - *Overlapping*



Simulation on an overset mesh

1. Generate surface meshes
2. Generate volume meshes
3. Specify initial conditions
4. Apply boundary conditions
5. Solve on each volume mesh
6. Interpolate flow data in overlapping regions
7. Repeat 4-6 until converged (steady results)



Geometric Model

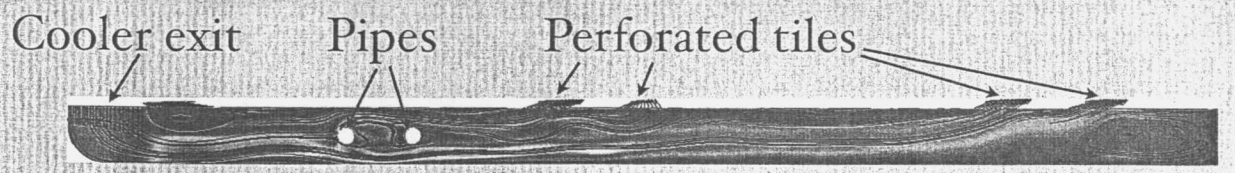
PDE Solution Model

- Overflow2 (NASA/Army developed)
  - *102 structured overset meshes, 12 million points*
  - *Solution of Navier-Stokes equations*
  - *Compressible, viscous flows*
  - *Low-speed pre-conditioner for accuracy*
  - *Obtain steady-state*
  - *Result: flow field / temperature field*

Approach

- Develop geometric model
- 2D sub-floor model
- Develop necessary boundary conditions
- 3D main-floor model
- Flow visualization

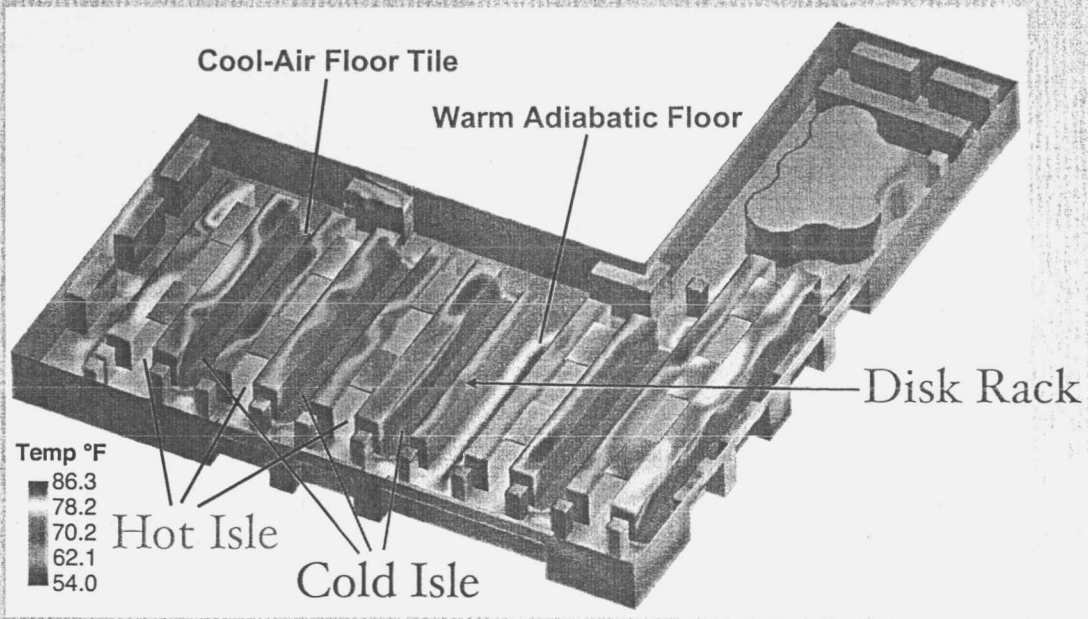
2D sub-floor



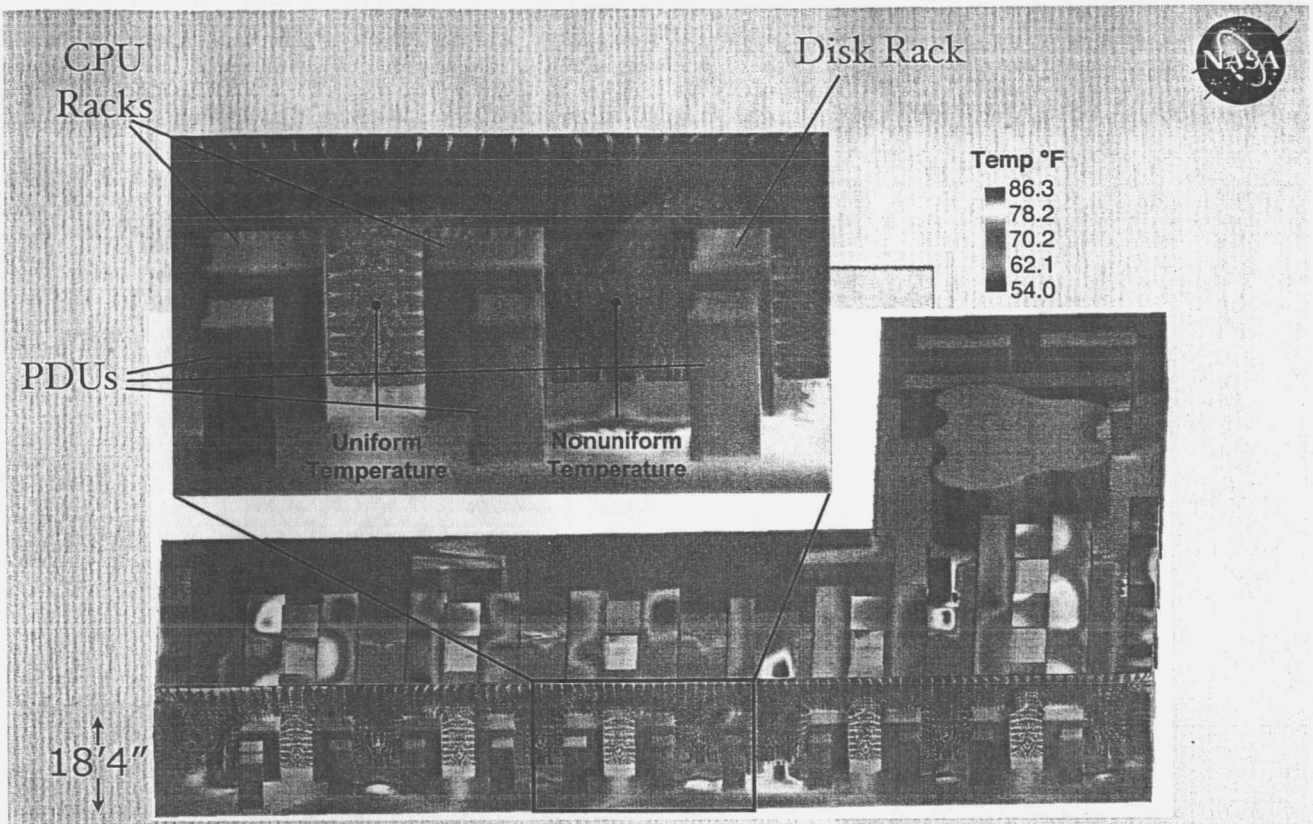
- *Simulation indicates that pipes blocking sub-floor flow have little effect on the perforated tile flow rates*
- *Literature: A full three dimensional sub-floor simulation with pipes and conduits found little flow rate variation in floor tiles except near coolers.*
  Karki, K.C., Radmehr, A., and Patankar, S.V., "Use of Computational Fluid Dynamics for Calculating Flow Rates Through Perforated Tiles in Raised-Floor Data Centers," HVAC&R Research Journal, Vol. 9, No. 2, April 2003, pp. 153-16
- **REASONABLE ASSUMPTION: THE COOLER FLOW RATE IS EVENLY DISTRIBUTED AMONG ALL THE PERFORATED FLOOR TILES**

Boundary Conditions

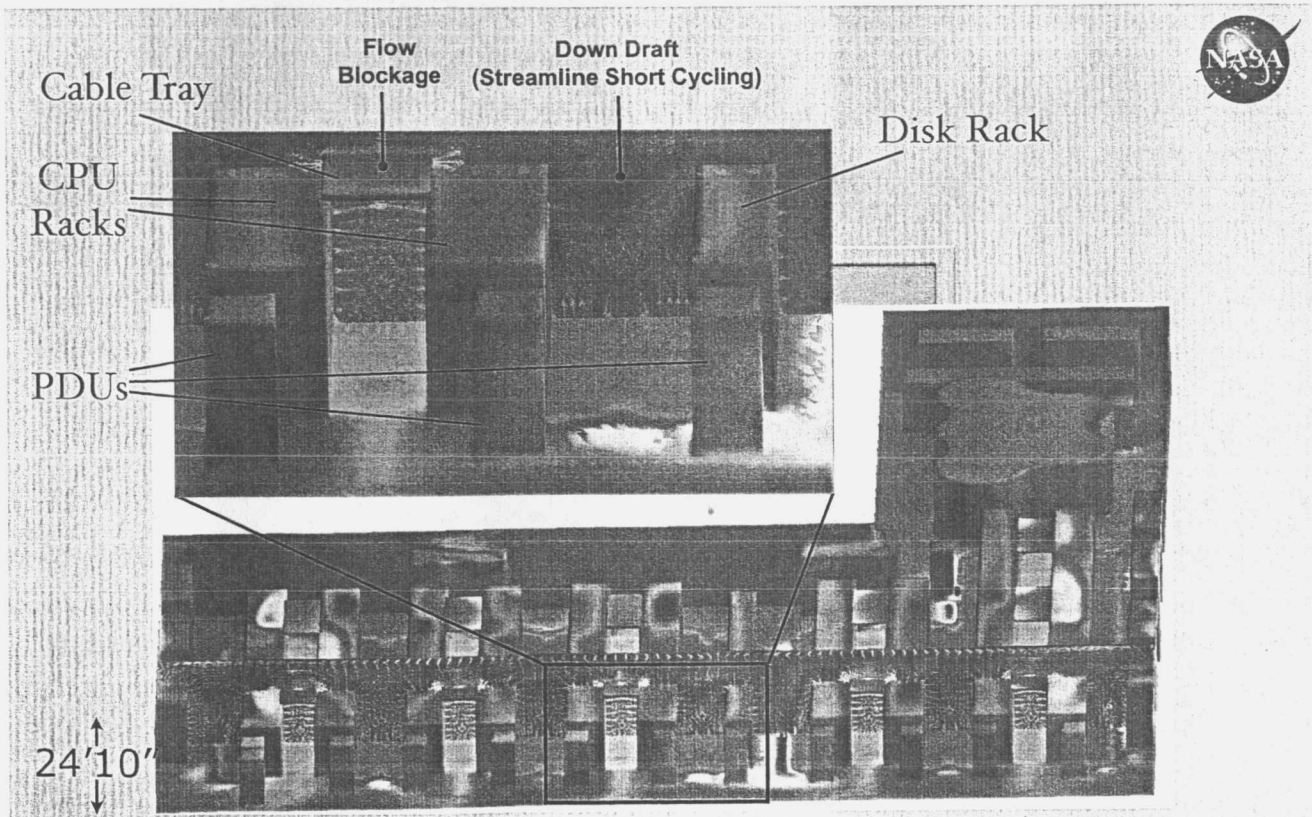
- Perforated tiles: Temperature, speed known
- Rack intake: Speed based on fan rating
- Rack exit: Known temperature increase
- Cooler intake: Known speed based on CFM rating



Surface Temperature



Temperature/velocity vectors



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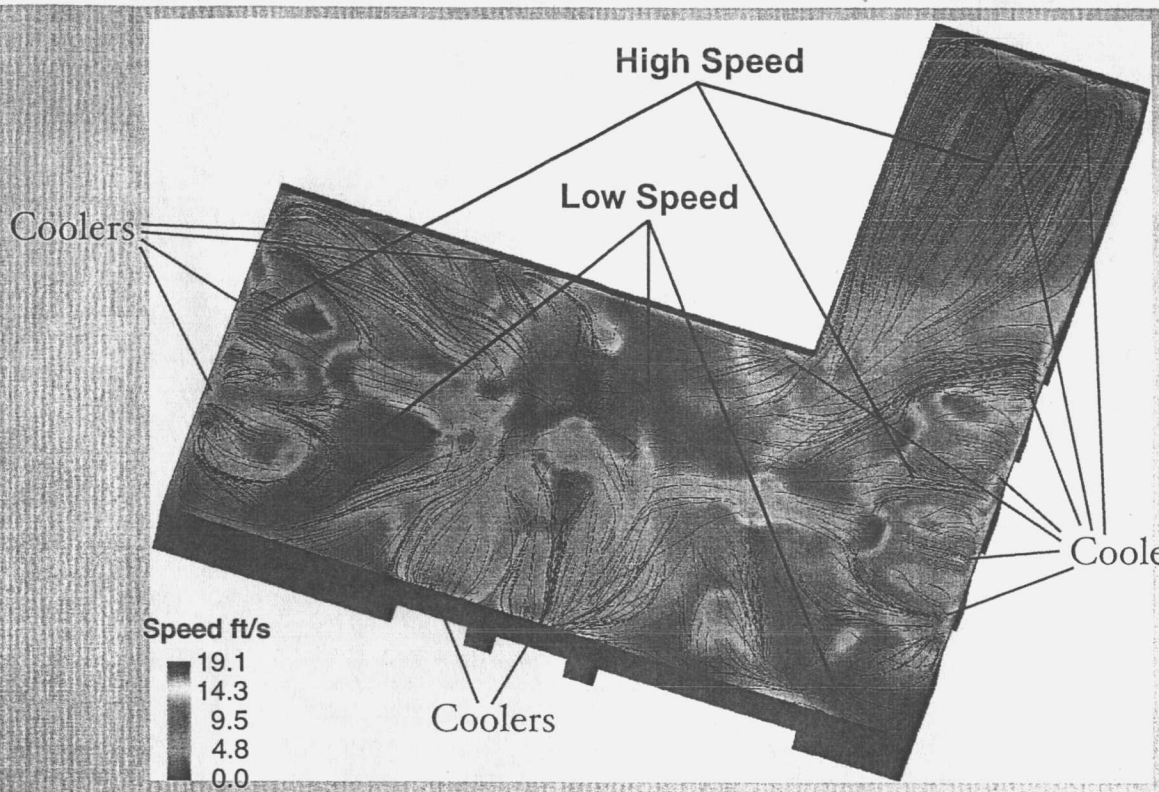

Speed / Flow stream lines

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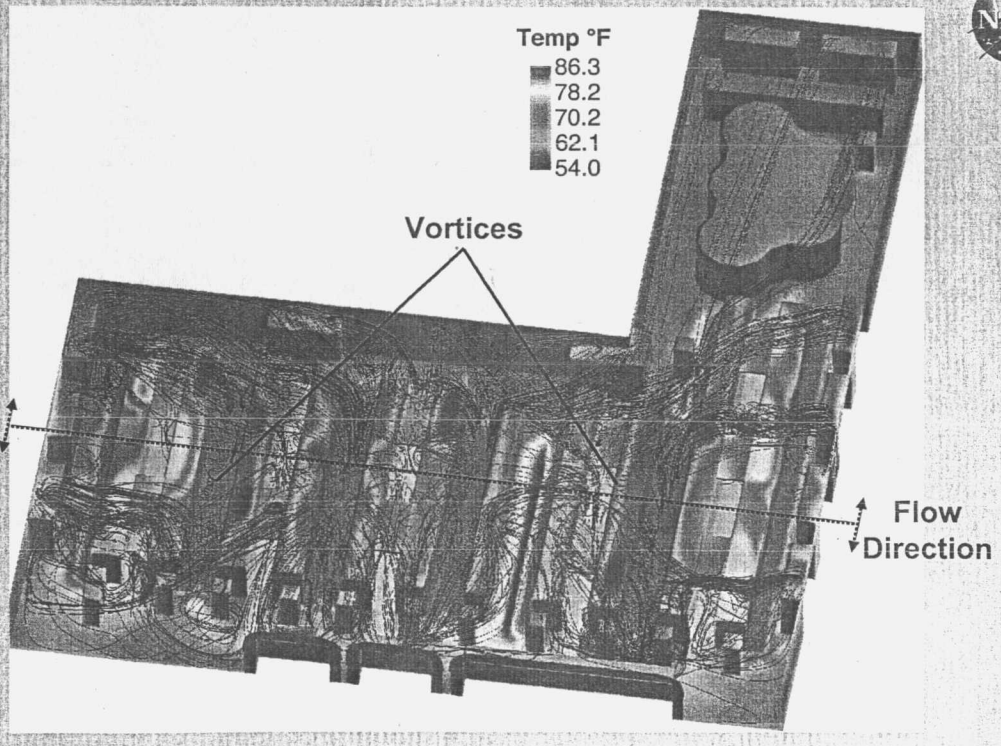

Flow Stream Lines / Surface Temperature

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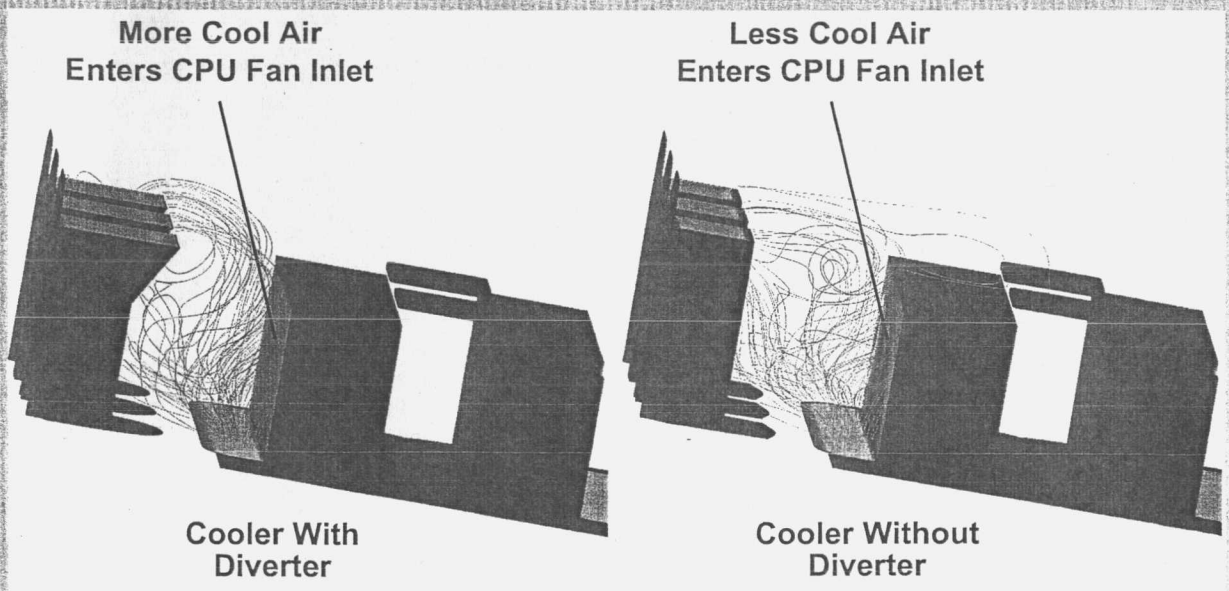
Short cycling



Possible Modification: Diverter on Cooler

Concluding Remarks

- Used overset mesh technology to evaluate the fluid/thermal character of a computer room
- Computed average temperature in room to certify the adequacy of the coolers
- Identified high temperature regions and dead-zones
- Improved understanding of effect of the cable trays on local temperature
- Identified short-cycling
  - *Tested possible modification to reduce short-cycling*